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Abstract

CORROSION OF REACTOR MATERIALS

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The results of the work are presented in two parts.

1. An electrochemical study of the effect of irradiation on the corrosion of some reactor materials.

Corrosion experiments on aluminium, zirconium, titanium, niobium, zircaloy-2, stainless steel and platinum have been carried out in-pile, and after pile irradiation, and the results have been compared with those obtained out-of-pile under identical conditions. Electrochemical techniques were applied as testing method. The in-pile measurements consisted either in measurement of the time necessary to build up a potential at a given constant electric current (transitometric method) or in measurement of the electric current as a function of changing potential (potentiodynamic method). The post-irradiation experiments were done by oscillographic recording of the overpotential versus the time when a single charge pulse was supplied to the specimen. The in-pile measurements were done in aqueous solutions, the irradiation of specimens for the post-irradiation examination in mixtures of dried argon and oxygen and in high purity argon.

In the case of aluminium it was found that the passivation properties of the oxide layer formed during pile irradiation in aqueous solutions were superior to that formed in the absence of radiation.

Potentiodynamic measurements on steel 316L and on platinum showed that in acid, neutral and alkaline solutions the zero-current potential during irradiation shifts to the cathodic direction. When the solution only is irradiated a similar shift occurs. This may indicate that by irradiation the solutions become relatively more reducing. The anodic current with increasing potential is under irradiation in all solutions higher than in the absence of irradiation. This increase was most pronounced in acid solutions and least in alkaline solution. The nature and quantity of dissolved gases have some importance but the effects are not well understood.

The effect of chloride concentration on pitting corrosion of steel has been studied. The results indicate that in-pile the onset of pitting attack is retarded in comparison with out-of-pile experiments.

The study by means of the single charge pulse method showed that the thickness of the passivating oxide films on zirconium, zircaloy-2, titanium and niobium increased during irradiation in dried argon-oxygen mixtures at 20°C. A pure gamma irradiation of these metals in a mixture or argon-oxygen increased the oxide thickness to about the same extent.

2. The influence of surface treatment on the behaviour of carbon steels and stainless steels in water and steam at high temperature.

The influence of surface treatment on the oxidation of metals, as observed in many cases, indicates the usefulness of a systematic study of this factor in the oxidation of steels in high temperature water and steam. This problem has a special importance for the construction of nuclear reactors of the PWR and BWR type.

Two steel varieties have been studied : a low-alloyed carbon steel and a stainless steel type AISI 304. Four surface treatments have been chosen initially : electropolishing in an acetic-perchloric acid bath, under-water mechanical polishing on paper SiC up to grid 600, grinding and milling.

a) In the first part of the study, these steels have been autoclaved in water at 300°C and in steam at 400°C and 200 kg/cm^2 for periods up to 2000 hours.

The results show a very beneficial effect of the electropolishing treatment at both temperatures. The corrosion rate on the electropolished samples is 2 to 3 times lower than on the mechanically prepared samples. The corrosion rate is highest on the milled samples.

As to the stainless steel, the effect of electropolishing is even more marked but only in water at 300°C. In steam at 400°C the mechanically prepared samples turn out to be much better.

Statistical evaluation of a large number of results showed that the observed differences were entirely meaningful.

b) Following these results, a second part of the study comprised the evaluation of the effect of surface treatment on the corrosion of stainless steels for a wider temperature range (200°C to 500°C).

This has been done in order not only to specify the best surface treatment for the use of these steels at different temperatures, but also to gain insight into the oxidation kinetics of 18-8 steels, which change with the mechanical preparation of the surface.

c) At the same time, the different characteristics of the sample surfaces have been defined. The roughness has been measured by means of a profilograph. The thickness of the passivation layers has been measured before introduction of the samples inot the autoclaves, by means of an electrochemical method (coulometry at constant current density). The deformed surface layer has been estimated by following the broadening of diffraction lines.
Finally, the morphology of the oxide layers, formed at different temperatures and after different surface treatment, has been checked by optical and electron microscopy.

These supplementary tests helped in distinguishing the separate influence of each characteristic of the surface on the corrosion.